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Department of Plant Pathology

An unsprayed apple tree defoliated by the Frog-Eye Leaf Spot. Photographed September 10th, when the tree still should have been in full leaf. The fruit buds have been so poorly nourished that there is small prospect of a crop next year.

FOLIAGE DISEASES OF THE APPLE.

REPORT ON SPRAYING EXPERIMENTS IN 1910 AND 1911

BY
HOWARD S. REED, J. S. COOLEY,
AND J. T. ROGERS

BLACKSBURG, MONTGOMERY COUNTY, VIRGINIA

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Foliage Diseases of the Apple[a]

By Howard S. Reed, J. S. Cooley, and J. T. Rogers.

This bulletin is based upon experiments made by the Virginia Experiment Station during the years 1910 and 1911, in the Valley and Piedmont regions. Experiments on these diseases are still in progress, but the results already in hand will be presented here. Some of the organisms causing these diseases are now known and experiments have been made for their treatment. Not one, but several, fungi are involved in the so-called Frog-Eye leaf spot. It has been found that the application of Bordeaux mixture or dilute Lime-Sulphur solution at the proper time will control the Scab and Frog-Eye leaf spot, but not the Cedar Rust. The relative merits of these sprays are explained, and the nature and cause of spray injury are also briefly discussed, with directions for avoiding spray injury.

Amount of Injury Caused by Foliage Diseases.—The injury caused by foliage diseases is often underestimated. Any injury to the foliage will weaken the vitality of the entire tree, for the leaves are important organs of digestion and assimilation.

Weakened foliage or early defoliation affects every function of the tree; it affects the size, color, and quality of the fruit as well as the growth and general vigor of the tree. Furthermore, the fruit buds for the crop of the following season are weakened. Recent research[b] at this Experiment Station showed that the fruit buds of the apple crop for the following season can be seen the latter part of June, and continue their development throughout the remainder of that season. It is evident, therefore, that anything that affects the vitality of the tree during its period of bud formation affects the vitality of the fruit buds of the following year. This is shown by the weak blossoms, or lack of blossoms, which follow a severe attack of foliage disease.

The harmful effect of foliage disease is also witnessed in the poor growth and small, colorless, insipid fruit which trees badly infected with foliage diseases produce.

THE FROG-EYE LEAF SPOT.

Throughout the orcharding sections of the State a leaf disease known as Frog-Eye spot is more or less prevalent. When conditions are favorable for the development of the disease, it may cause the leaves to fall early enough for a new crop of young leaves to put forth the same season. Since the injury

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[a] Publication No. 16 from the Laboratory of Plant Pathology, Virginia Agricultural Experiment Station.

[b] Drinkard, A. W. Fruit-Bud Formation and Development. Annual Report of the Virginia Agricultural Experiment Station, 1909-10.

is chiefly to the foliage, it is impossible to estimate the loss; but it is undoubtedly far greater than is commonly supposed.

The Frog-Eye leaf spot is not confined to any one part of Virginia, but it is likely to be noticed in all places where extensive orchards are found. Throughout the western part of the State it does considerable damage every year, even in such unfavorable seasons for its development as the dry summer of 1911. The order of the prevalence of Frog-Eye spot in the several sections of the State is as follows: Southwest, Piedmont, Tidewater, Valley, and Middle Virginia.

FIG. 1.—Frog-Eye spot on apple leaves.

Description of the Disease.—The Frog-Eye disease produces on the leaf circular or elliptical dead spots varying in size from one-eighth inch in diameter to nearly an inch or larger, where several spots grow together. (Figs. 1 and 2). The spot is brown, or brown interspersed with gray rings. In the center of a mature spot is a gray or *whitish gray* disk from one-sixteenth to one-eighth inch in diameter, which is generally surrounded by one or more dark concentric rings. The Frog-Eye spot begins as a small light brown or gray spot that generally appears in early summer. When this young spot is from one-sixteenth to one-eighth inch in diameter, a definite margin is formed, this margin being surrounded by a sharp indenture or furrow that in turn is surrounded by a slightly elevated ring having a dark color. In a short time this

whitish gray central spot is gradually surrounded with a widening zone of dead brown tissue, until a single spot may become nearly an inch in diameter. It is this brown ring surrounding a light center that gives the spot its characteristic target or "Frog-Eye" appearance. On closely examining the spot we find the gray center and sometimes the brown margin studded with small black pimples called "pycnidia." These pimples contain the spores or reproductive bodies of fungi, some of which are responsible for the disease, and others merely live on the tissues killed by the first class.

Conditions Favorable for Development. — Warm, rainy seasons favor the development of most fungous diseases; Frog-Eye leaf spot is no exception to the rule. If the weather during the spring and summer months is warm and "muggy" there is greater foliage injury from this disease than if the season is cool and dry. The site of the orchard is also important. Trees in hollows and on northern exposures generally have more leaf spot than trees on southern or eastern exposures, because the foliage does not dry quickly after rains or heavy dews and therefore conditions are much more favorable for fungous diseases. Clean cultivation also tends to lessen the injury caused by leaf spot, because it not only makes the trees more vigorous, and hence more resistant to disease, but also destroys the fallen leaves, which are a source of infection.

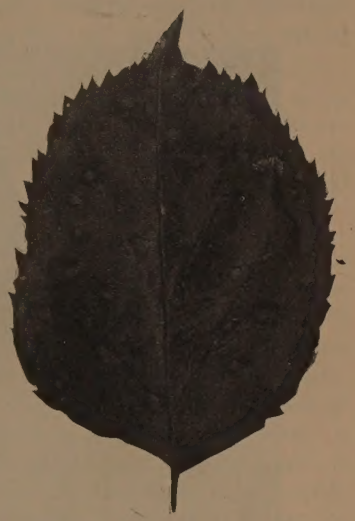

FIG. 2.—Typical Frog-Eye spot on apple leaf, showing the concentric rings around a lighter colored central spot. Spraying with Bordeaux or lime-sulphur is effective.

The disease is more common on certain varieties of apples than upon others. Ben Davis and Black Twig are among those more severely attacked. The York Imperial does not suffer so severely from the Frog-Eye leaf spot, and the Winesap suffers even less.

How the Disease is Carried over Winter.—We believe that the fungi causing Frog-Eye spot is carried over winter by the spores in the fallen leaves. In the spring the spores are liberated and carried to young apple leaves. During cloudy or rainy days these spores germinate and grow down into the leaf, and produce the dead spot described above. This, therefore, is another reason for cultivation; when diseased leaves lying on the ground in early spring are plowed under, a source of infection for that season is removed.

CEDAR RUST.

Cedar Rust is one of the most virulent foliage diseases in this State. (Fig. 3.) In some sections of the Valley it has caused great injury to susceptible varieties, such as the York Imperial. The Cedar Rust fungus passes part of its life upon the red cedar and part upon the apple. On the cedar it produces galls commonly called "Cedar Apples." The first indication of this disease on the apple is the appearance of yellow spots on the upper surface of the leaves, containing pimples or pustules that soon turn black. After some weeks there

FIG. 3.—Apple leaf spot caused by the Cedar Rust fungus. This disease causes serious defoliation of many orchards, especially in the Valley of Virginia. Spraying not very effective. Destroy all cedar trees within half a mile of the orchard.

is formed in the infected spot, but on the under surface of the leaf, a thick, spore-bearing cushion from which small tubes project. These tubes soon split and curl back on the leaf, thus giving a hairy appearance. The yellow spot on the upper surface usually appears in May, while the cushion on the under surface of the leaf does not generally give forth spores till June or July. The fungous spores from the apple leaves are widely dispersed by the wind, but only those develop which fall upon red cedar trees. Similarly, the spores liberated from the cedar trees in the spring are widely dispersed by wind, and only those develop which fall upon the apple. This Rust often causes considerable defoliation by August; as a result the tree makes poor growth, the

fruit is small, poorly colored, and insipid. York Imperial, Jonathan, and Rome Beauty are the most susceptible of the leading commercial varieties, Grimes Golden and Ben Davis are moderately susceptible, Winesap, Mammoth Black Twig, Northwestern Greening, and Albemarle Pippin are more or less resistant to the Cedar Rust.

Experiments looking toward the control of the Cedar Rust by spraying are being conducted by this Experiment Station. No entirely satisfactory spray has been found up to the present time. Lime-sulphur has only moderate value; Bordeaux is better, but is far from successful. Several new spray solutions are being tried, but no definite recommendations in regard to them can be made at present.

The most satisfactory practice we now know consists in the removal of the red cedar trees in the vicinity of the orchards. The spores of the fungus are undoubtedly carried long distances by the wind, but if the cedar trees are destroyed within a half mile of the orchard the most serious injury should be avoided.

APPLE SCAB AS A FOLIAGE DISEASE.

The leaf spot produced by the scab fungus, while not so prevalent as the Frog-Eye spot, is injurious. In certain sections of the State, especially in the Southwest, the disease is more prevalent in cool, moist seasons. This fungus attacks both the fruit and the leaf. On the fruit it produces the corky, olive-green or black spot that is so familiar to all fruit growers. The loss caused by this disease to the fruit crop of this State is considerable every year. A mature scab spot on the leaf differs quite materially from a Frog-Eye spot. It is olive green to black, irregular in outline, and has a rough, thickened appearance on the upper surface. This spot does not possess the smooth upper surface, the light center and zonate appearance that characterizes a Frog-Eye spot. On the surface of these leaf spots numerous spores are produced which mature quickly. These spores, when mature, are blown or washed to other leaves or fruit.

During the winter months the scab fungus continues to develop on the fallen leaves, and matures the resting spore late in February or early in March. Fig. 4 is a micro-photograph made from an apple leaf collected at Blacksburg on February 25th, 1911. This shows the spore sacs and the conceptacle in which they are formed. The resting spores are set free in early spring and are ready to infect the young foliage. Our experiments at Fontella showed that an application of spray before the trees bloom is necessary to prevent this early scab infection. If the orchard is plowed early in the spring large numbers of these resting spores will be buried in the soil to a depth which prevents them from becoming a source of infection.

It is obvious, therefore, that an early spraying, just before the blossoms open, is very important in preventing the leaf form of the scab and therefore the attack upon the fruit; especially for varieties like Winesap and Albemarle Pippin, which are quite susceptible to scab.

SPRAYING EXPERIMENTS FOR THE CONTROL OF FOLIAGE DISEASES.[a]

During the seasons of 1910 and of 1911 the department of Plant Pathology conducted spraying experiments for the control of diseases of apple foliage. In 1910 experiments were conducted in the Piedmont at Fontella, Bedford County; and in the Valley at Harrisonburg, Rockingham County. In 1911

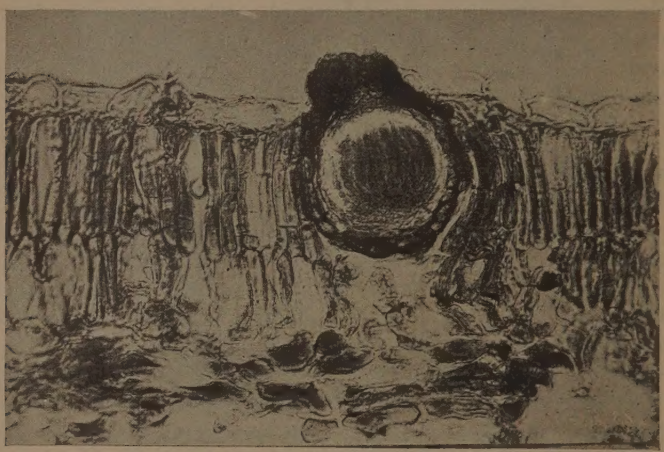

FIG. 4.—Apple Scab in Winter. This micro-photograph was made from a section of an apple leaf collected late in February. It shows the spores of the disease developing within a sac in the leaf. If the leaves are plowed under before April the amount of scab will be reduced.

experiments were conducted near Middletown in Frederick County, and at Strasburg in Shenandoah County. The season of 1910 was not very favorable for the development of the diseases known as "Frog-Eye" and the season 1911 (marked as it was by drought) was still less favorable. The most important

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*a*We wish here to acknowledge the friendly coöperation of those in whose orchards these experiments were conducted, viz.: Messrs. A. Von Ammon and G. E. Murrell of Fontella; S. L. Hoover of Harrisonburg; Larrick and Larrick, A. Forney, and Edgar MacDonald of Middletown; J. H. Pifer of Strasburg. In 1910 we received the aid of Mr. A. W. Drinkard, Jr., Assistant Horticulturist of this Experiment Station.

results of these experiments were the demonstration of the value of lime-sulphur preparations for spraying certain varieties of apples; the time at which Bordeaux injury arises; and the reasons for spraying before the blossoms open.

In recording the results of the experiments little attention was paid to the comparative yield of the sprayed and the unsprayed trees, since the trees in the different orchards were of different ages and varied considerably in the amount of bloom and consequently in the amount of fruit set. Unless the trees are of the same variety, have the same cultivation, and bloom the same, it is very difficult, if not impossible, to tell how much difference is due to spraying. Furthermore, the benefits of destroying the foliage diseases are by no means entirely shown the first year. It was perfectly obvious, however, that the fruit of the sprayed trees was improved both in quality and quantity over that of unsprayed trees.

The Spray Mixtures Used.—1. Commercial Lime-Sulphur (testing 32°-33° Beaumé) diluted at the rate of 1½ gallons to 50 gallons water.

2. Bordeaux mixture (4 pounds copper sulphate, 5 pounds lime, 50 gallons water.)

3. Iron-Bordeaux; made by adding 3 pounds of iron sulphate (copperas) to 50 gallons of Bordeaux mixture.

4. Iron-Lime-Sulphur; made by adding 3 pounds of iron sulphate (copperas) to 50 gallons of the diluted lime-sulphur spray noted above.

The insecticide added for the control of codling moth was arsenate of lead at the rate of 2 pounds to 50 gallons of each of the above spray mixtures.

When the check trees were set with fruit, they were sprayed with arsenate of lead alone at the rate of 2 pounds to 50 gallons of water.

EXPERIMENTS AT FONTELLA IN 1910.

The Fontella orchards are quite typical for Blue Ridge and Piedmont conditions. At this place spraying experiments were conducted upon Winesap and Ben Davis. The trees were about 18 years old; they had been quite severely attacked by the Frog-Eye disease the preceding year. The first spray was applied April 6th, just as an unusually early bloom was falling from the trees. The leaves were at that time about 1 inch long. The spraying was done according to the plan shown in Table I. Part of the trees received five sprayings while others received only four, the first spraying being purposely omitted.

TABLE I.

Experiments at Fontella in 1910.

Plots.	Variety.	Dates of Spraying.	Spray Material Used.
I.	Winesap	April 6, April 28, May 28, June 21, July 20.	Bordeaux.
II.	"	April 28, May 28, June 21, July 20.	Bordeaux.
III.	"	April 6, April 28, May 28, June 21, July 20.	Lime-Sulphur.
IV.	"	April 6, April 28.	Check (arsenate of lead).
V.	Ben Davis	April 6, April 28, May 28, June 21, July 20.	Lime-Sulphur.
VI.	" "	April 28, May 28, June 21, July 20.	Lime-Sulphur.
VII.	" "		Check (unsprayed).

On April 28th, the foliage of the unsprayed Winesap trees began to show chocolate-colored spots, which were classified as incipient "Frog-Eye" or Scab, or both. As many as 10 or 12 spots were present on some of the unsprayed leaves, but few were found upon the leaves of the sprayed trees of Plots I, III, and V. The trees of Plots II and VI showed a greater infection of both Cedar Rust and Frog Eye throughout the summer than those of Plots I, III, and V, which received the earlier spraying. The trees of Plots III, V, and VI (which received lime-sulphur, 1½ to 50) appeared to have somewhat more fungous disease about July 20th than the trees of Plots I and II, which received 4-5-50 Bordeaux. By the end of the season, however, very little difference could be seen in the amount of foliage disease on the two sets of trees. Leaf spots were not numerous and the trees retained their foliage well. The trees of Plot III showed a little more scab than those of Plots I and II, but very much less scab than those of Plot IV (unsprayed).

The Ben Davis trees of Plots V, VI, and VII were under the brow of a steep wooded hill, where conditions were more favorable than usual for the development of fungous diseases. The lime-sulphur sprays kept the trees of Plots V and VI very free from the Frog-Eye disease. Cedar Rust was more abundant upon trees in Plot VI. We believe that this was due to the fact that the trees of Plot V were sprayed 22 days earlier than those of Plot VI.

Great improvement was shown in the foliage of the sprayed trees when compared with that of the unsprayed trees. An example of the effectiveness of this treatment is shown by a comparison of figures 5 and 6.

The fungicidal value of arsenate of lead alone was demonstrated on the Plot IV used in this experiment. This plot was sprayed with arsenate of lead alone at the rate of 2 pounds to 50 gallons of water. A few trees in the vicinity were inadvertently left without any spraying whatever. At the end of the season, the foliage of these trees was in worse condition than that of the

Fig. 5.—An unsprayed Ben Davis tree in the Fontella experiment. Photographed August 29th. Compare Fig. 6.

trees sprayed with arsenate of lead alone. It would seem that arsenate of lead has some slight fungicidal value, but not of sufficient value to depend upon it alone for controlling diseases. Wallace, Blodgett, and Hesler[a] found by laboratory tests that pure arsenate of lead in water at the strength that it is commonly used in spraying prevented many fungous spores from germinating; and that it reduced the amount of fungous disease on the sprayed trees.

[a]Wallace, Blodgett, and Hesler, Studies of the Fungicidal Value of Lime-Sulphur Preparations. Bulletin 290, (Cornell) Agricultural Experiment Station, 1911.

EXPERIMENTS AT HARRISONBURG IN 1910.

The experiments at Harrisonburg were conducted in an orchard believed to represent conditions typical of that part of the Valley. York Imperial and Ben Davis trees were used. The first application of spray material was made April 9th, when less than one per cent of the bloom buds were open. Some of the trees were 10 years old and others were approximately twice that age. The plan of the spraying experiments is shown in Table II. The York trees were sprayed six times, the Ben Davis five times, and both check plots three times with arsenate of lead alone.

TABLE II.

Experiments at Harrisonburg in 1910.

Plots.	Variety.	Dates of Spraying.	Spray Material.
I.	York	April 9, April 22, May 10, June 7, June 23, July 22.	Bordeaux.
II.	"	April 9, April 22, May 10, June 7, June 23, July 22.	Lime-Sulphur.
III.	"	April 22, May 10, June 7.	Check.
IV.	Ben Davis	April 22, May 10, June 7, June 23, July 22.	Bordeaux.
V.	" "	April 22, May 10, June 7, June 23, July 22.	Lime-Sulphur.
VI.	" "	April 22, May 10, June 7.	Check.

Frog-Eye spots and Cedar Rust were first noticed on the York trees about May 10th. The amount of Cedar Rust on June 7th on the unsprayed trees was seen to be distinctly greater than on the sprayed trees. At the end of the season the amount of Cedar Rust on the unsprayed trees was much greater in Plot III than in Plots I and II. Upon close inspection it was found that the Bordeaux mixture (Plot I) was slightly more efficient in checking the Cedar Rust than the Lime-Sulphur mixture (Plot II). The Frog-Eye disease was controlled equally well by the two spray mixtures.

The Ben Davis trees of Plot IV showed Bordeaux injury in the form of russeting on June 7th; i. e., after two applications of spray mixture. This russeting increased as more applications of spray mixture were made. The leaves were, however, kept free from fungous diseases, but at picking time 95 per cent of the apples were russeted by the spray. As in the case of the Yorks, men-

tioned above, there was more Cedar Rust at the end of the season on the foliage of the trees sprayed with lime-sulphur (Plot V) than upon those sprayed with Bordeaux (Plot IV). The Frog-Eye disease was controlled equally well by both spray mixtures. A small amount of spray injury was shown by the trees sprayed with lime-sulphur.

FIG. 6.—A Ben Davis tree sprayed four times with Bordeaux mixture. Note the abundance of the foliage and fruit. Photographed August 29th. Compare Fig. 5.

The Bitter Rot became quite prevalent on the trees of Plot V (lime-sulphur), but in Plot IV (Bordeaux) the loss from this disease was only 3 to 4 per cent. Other experimenters also have found that lime-sulphur fails to control Bitter Rot.[a] It has been found entirely practicable to use lime-sulphur for the first three sprayings needed for the control of Scab and Frog Eye and then to use Bordeaux mixture for later sprayings to control the

[a]See Scott, W. M., Report Virginia State Horticultural Society, 1910, p. 180.

Bitter Rot. The usual time for beginning the Bordeaux applications for Bitter Rot is seven to nine weeks after the petals have been shed, making two or three applications at intervals of two or three weeks.

EXPERIMENTS AT MIDDLETOWN IN 1911.

As a result of the extremely dry season at Middletown in 1911, the amount of fungous disease on apple trees was very slight. Nevertheless it may be worth while to mention the plan of the experiments, which is outlined in Table III, and to discuss the results briefly.

FIG. 7.—Leaves from an unsprayed Ben Davis tree in the Fontella experiment. Collected July 20th. Note the Frog-Eye spots and dead tissue. Compare Fig. 8.

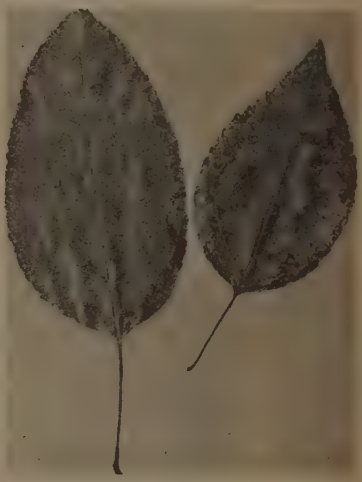

FIG. 8.—Leaves from a Ben Davis tree sprayed with lime-sulphur in the Fontella experiment. Collected July 20th from a tree near that from which leaves shown in Fig. 7 were taken. The spots are spray material, not disease.

The first applications of spray material were made about three days before the blossoms began to unfold and five to seven days before the trees were well in bloom. The trees had a vigorous coat of leaves, many of them full-sized, when the second application of spray material was made, on May 16th. Following the application of the first spray the weather was very dry. Light showers on April 29th and a rain on May 1st were not sufficient to remove much of the spray material. Consequently the first application remained upon the leaves and prevented fungous infection.

Between the applications made on May 16th and June 3d no rain fell, except a light shower on May 31st. Therefore, up to the time of the third spraying there was practically no fungous infection owing to the drought conditions which existed. Soon after the third application there were three or four days of misty weather during which there was considerable fungous infection on leaves which had emerged previous to that time. The majority of the infections were produced by the Cedar Rust fungus, the Frog-Eye fungi being in the minority.

TABLE III.

Experiments at Middletown in 1911.

Plots.	Variety.	Dates of Spraying.	Spray Material.
I.	York	April 26, May 16, June 1.	Lime-Sulphur.
II.	"	April 26, May 16, June 3, June 21.	Lime-Sulphur.
III.	"	April 26, May 16, June 1.	Bordeaux.
IV.	"		Check (unsprayed).
V.	Winesap	April 26, May 16, June 1.	Bordeaux.
VI.	"	April 26, May 16, June 1.	Lime-Sulphur.
VII.	"		Check (unsprayed).
VIII.	York	April 27, May 17, June 3.	Iron-Bordeaux.
IX.	"	April 26, May 16, June 1.	Iron-Lime-Sulph'r.
X.	"		Check (unsprayed).
XI.	Ben Davis	April 27, May 17, June 3.	Lime-Sulphur.
XII.	" "	April 27, May 17, June 3.	Iron-Lime-Sulph'r.
XIII.	" "		Check (unsprayed).

This short break in a drought which extended from May 1st to August 1st led to an observation on the time at which apple leaves are capable of fungous infection. Fungous infection occurred on two places of the season's growth, first, on two or three leaves at the base of the season's growth which unfolded at, or prior to, the blooming period; second, on three or four leaves in adjoining whorls which unfolded just prior to the moist period in June above mentioned. This condition shows a fact not easily ascertained in ordinary years; that there is only a short period in which a leaf is susceptible to infection by diseases. This emphasizes the necessity of having the leaves covered with spray mixture as soon as possible after they unfold.

At the end of the growing season practically the only infection to be seen on the foliage was that produced by Cedar Rust, and these spots were only on the leaves described above. The efficiency of the different sprays was estimated by counting the number of spots upon the individual leaves, on similar twigs of the experiment trees. The results of counting several thousand leaves did not speak highly for the preventive action of any of the spray solutions used for Cedar Rust. Bordeaux and Iron-Bordeaux restricted slightly the amount of Cedar Rust, as in the previous year's experiments at Harrisonburg. Lime-sulphur and iron-lime-sulphur had no noticeable effect upon the amount of Cedar Rust infection. There was no appreciable difference between the amount of Rust infection on the unsprayed trees and on those that were sprayed with

FIG. 9.—Apple leaves injured by lime-sulphur spray. Note that the leaves have been killed at the margin. This is due to the tendency of the spray solution to collect at the margin, especially at the lower edge of the leaves.

lime-sulphur. The addition of iron sulphate improved the sticking properties of both Bordeaux and lime-sulphur, but otherwise did not appear to affect their fungicidal action.

SPRAY INJURY.

While carrying on spraying experiments during the past two years we have studied spray injury. Without spraying it is impossible to raise profitable crops of fruit, no matter how well the orchard may otherwise be cared for. But unless spraying is carefully done, and the right kind of spray used, there is danger that fruit may be injured.

The spray solutions commonly used for combating the pests of the orchard are poisonous substances and their value lies in this fact. They are designed to kill the tender young stages of fungi and insects. When a fungous spore ger-

minates it puts out a delicate filament which must grow a greater or less distance on the plant before it penetrates into and develops within the plant. In the young stages it is possible to apply a poison strong enough to kill this delicate filament from the sprouting spore; and weak enough, usually, to avoid injury to the plant.

Types of Spray Injury on Leaves.—The leaves which receive most of the spray may be injured to a varying extent. In spring, when the leaves of certain varieties are quite tender, they may be dwarfed by spray injury. This injury

FIG. 10.—Leaves of Albemarle pippin "scalded" and spotted by Bordeaux mixture. Note that the worst scalding occured at the margin of the leaves.

is caused usually by the application of spray before the trees bloom. The effects of this spray material may hold back the growth of the foliage of the tree for two or three weeks. Lime-sulphur is especially apt to cause dwarfing of the leaves.

The bulged or one-sided leaf (Fig. 9) is a type of injury resulting from killing the tissues at the margin of the leaves, wholly or in part. This is perhaps the most common type of spray injury. It seems to develop somewhat as follows: After the application of the spray material, if the weather is dry the spray water quickly evaporates, but in cool or moist weather it may stand on the leaf for some time. Even if the spray water is evaporated, rains or heavy dews may dissolve the poisonous agents and keep them in solution on the

leaf for some time. In either case the solution has a tendency to collect at the edge of the leaf. This accumulation of the poisonous material at the margin of the leaf may bring about a concentration there five or ten times greater than that of the spray originally applied. This concentration eventually becomes so great that it kills the leaf tissues in that region. Many times only the apex of the leaf is killed. This will be found to occur when the leaf hangs more or less vertically downward.

A general "scalding" effect (Fig. 10) is more rarely noticed, especially when warm, moist weather follows the application of the spray material. These leaves appear to be rather uniformly scalded and soon drop, whereas those which are only dwarfed or burned on the marginal areas usually hang on the tree for a considerable time.

"Spotting" is another type of spray injury, liable especially to be caused by Bordeaux. The dead spots produced are sometimes very similar in size and appearance to those produced by fungous diseases. The injured leaves are on varieties that have smooth and slightly waxy foliage, which repels the film of spray liquid and facilitates the collection of the spray into drops, where it concentrates, and causes the injury.

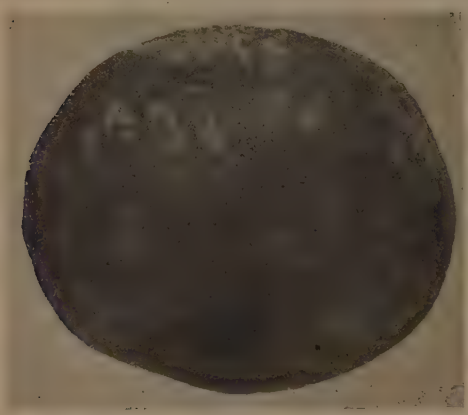

FIG. 11.—Russet of Ben Davis apple caused by Bordeaux mixture. The worst russet is produced by the first two applications of the spray mixture after blossoming.

Spray injury of the "shot hole" type is also frequently encountered, especially on the leaves of peach and plum. About ten years ago Professor B. M. Duggar, of Cornell, reported this and showed that the cause was due entirely to Bordeaux mixture. At present, however, very little Bordeaux mixture is used for spraying peach trees. Various lime-sulphur preparations, especially the self-boiled lime-sulphur, have been much more successful, with slight chances of injury to the foliage; but even with them spray injury sometimes occurs. On apple foliage the spray material sometimes causes death of the tissues in circular or elliptical spots, but the spots seldom fall out.

TYPES OF SPRAY INJURY ON FRUIT.

Russeting of the skin is a common type of spray injury. (Fig. 11.) Some varieties of apples with tender skins are more apt to russet than others. Some apples will russet even when unsprayed. Such varieties as Ben Davis, Black Twig, Jonathan, Baldwin, Greening, Limber Twig, and Gano are often badly russeted as a result of using Bordeaux mixture. Other varieties, as Paradise Sweet, Winesap, York and Albemarle Pippin, are by no means exempt from russeting, although not as susceptible to the injury as apples of the Ben Davis type. It has sometimes been claimed that russeting only occurs when the Bordeaux mixture was deficient in lime, but this is not true. Bordeaux mixture made by using two pounds of blue-stone and 10 pounds of lime to 50 gallons of water has produced serious russeting.

FIG. 12.—Ben Davis apple injured by lime-sulphur solution. A condition occurring in late June. Probably caused by an application of spray on a hot, bright day.

Russeting is almost entirely due to the two applications of Bordeaux made just after blooming. Lime-sulphur can be profitably used for these two sprayings, and Bordeaux for subsequent sprayings, without much danger of russeting the fruit. It is perhaps safe to say that freedom from russeting apples has been one of the greatest inducements for the use of lime-sulphur sprays in place of Bordeaux mixture. In severe cases the young apples may be seriously cracked by the use of Bordeaux mixture. Half-grown apples sometimes show cracks extending nearly to the core from this cause.

Injury from Lime-Sulphur Sprays.—During the past two years, considerable scalding caused by lime-sulphur has been noted. (Fig. 12.) Lime-sulphur scald is usually, but not always, marked by a hard reddish-brown spot from a half to one inch in diameter on the side of the apple exposed to the sun. The dead, scalded tissue is reddish brown in color and slightly depressed below the general contour of the apple. In most cases the sound flesh does not crack away from the scalded area. This injury may be produced any time up to the first of July and does not seem to be dependent on moist weather. It seems to be produced on trees which were sprayed in the early forenoon of a bright hot day. The sun shining on the wet fruit seems to render the spray material much more injurious and the tissues are killed. York Imperial apples were most commonly affected during the past season, but the scald was by no means confined to this variety.

"Calyx burn" is a type of spray injury to young fruit which we have found a few times on Baldwin apples. It appears to be caused by the spray which enters the calyx cup at the first spraying made after blossoming. Up to the present no serious injury has been caused.

HOW TO PREVENT SPRAY INJURY.

To make Bordeaux mixture which will not cause injury, it is essential that a slight excess of lime be present. If Bordeaux is properly made the solution is a beautiful sky-blue color. If copper is in excess the mixture is some shade of green. The most accurate method is to remove a glassful of the mixture and to add to it a few drops of a solution of yellow prussiate of potash (which can be bought from a druggist). If the addition of this solution causes the formation of a dirty green precipitate it means that free copper is present and that more lime should be added.

It is well known that unless it is well agitated Bordeaux mixture tends to settle. If settling occurs it is liable to produce spray injury because the material is concentrated at the bottom of the tank.

The most common cause of lime-sulphur spray injury is a too heavy application. In the tops of high trees, where the foliage is more difficult to spray, there is less spray injury than on the lower limbs, where the men are apt to apply too much lime-sulphur. One should thoroughly cover the foliage with the spray material, but stop spraying just before the spray begins to drip from the leaves.

There is a general agreement that Bordeaux injury is quite closely dependent upon weather conditions. The greatest injury occurs in wet seasons, when a shower follows closely on the application of Bordeaux mixture. In the case of lime-sulphur solutions, however, it has not been possible up to the present to establish any correlation between injury and weather conditions. Foliage injury seems to appear without any relation to rainfall.

To a limited extent the concentration of the spray mixture determines the extent of spray injury. Other things being equal a stronger concentration is more likely to cause spray injury than a weaker one. For summer spraying of apples or pears a gallon of concentrated solution testing 32° Beaumé should be diluted to 33 gallons, and a dilution of 1 to 40 is probably safer, and equally as efficient. For the summer spraying of peaches, plums, and cherries the dilution should be 1 to 150.

These concentrations do not mean much if the foliage is drenched by the use of a nozzle which throws a coarse spray, or by having the nozzle held too long in one position. A 1 to 50 dilution applied in this way is more apt to burn than a 1 to 33 dilution properly applied. The best results will be obtained from the application of dilute solutions from a fairly fine nozzle held several feet from the foliage, and using a high pressure.

Effect of Adding Insecticides.—Arsenate of lead may be safely mixed with either lime-sulphur or Bordeaux. It actually increases the fungicidal value of the spray to which it is added and reduces the danger of spray injury. Our experiments show that the danger of injury from arsenate of lead is practically removed when it is applied in a lime-sulphur spray. A few cases of arsenate of lead have been reported to us, where it is possible that there was not enough agitation in the spray tank. Paris green is not as safe to use, and ordinarily is less efficient as an insecticide.

FIG. 13.—This apple was injured by lime-sulphur solution and subsequently decayed as a result of the injury.

SUMMARY.

1. The Frog-Eye leaf spot, a serious foliage disease of apples, is widely distributed in the western and southwestern portions of Virginia. Not one, but several, fungi are associated in the leaf spots. Cedar Rust, which is a serious foliage disease in many sections of the State, especially in the Valley, is caused by a fungus which alternates between the apple and the red cedar. The best remedy we now know is the removal of the red cedar trees from within one-half a mile of the orchard. As yet, no spraying treatment has been entirely successful. The Apple Scab fungus attacks both fruit and leaf, but in this State the disease on the leaf is not as serious as the Frog-Eye and Cedar Rust.

2. Experiments in 1910 and 1911 show that dilute lime-sulphur solution is as effective in controlling the Frog-Eye leaf spot and the Scab as standard Bordeaux mixture.

3. Where Scab is not abundant the first spraying should be made immediately after the bloom drops, followed by a second and third application at intervals of 15 to 20 days. Where Scab is abundant an application of spray material should be made just before the blossoms open. The three other treatments noted above should also be given.

4. Bordeaux mixture is the only spray known at present which will successfully combat the Bitter Rot. The first application should be made between June 20th and July 1st. Two subsequent sprayings should be made at intervals of 15 to 20 days. (See our Bulletin 142.) The danger of russeting fruit with Bordeaux is practically over at this time.

5. The addition of iron sulphate to lime-sulphur or to Bordeaux mixture improves the sticking properties of these sprays, but does not seem to affect their value for controlling these diseases.

6. The experiments showed that arsenate of lead, aside from being a good insecticide, has some value as a fungicide.

7. Spray injury to the foliage is sometimes caused when the leaves are drenched with spray or with improperly made mixtures. The fruit may be burned with lime-sulphur if sprayed in very hot weather. Russeting of fruit occurs under a variety of conditions, but is most common on tender skinned apples which have been sprayed early in the season with Bordeaux mixture. The danger of russeting is very slight two months after blooming and later. Use lime-sulphur for the first two sprayings. Cracking and calyx burn are types of spray injury of less common occurrence.

Correspondence Concerning Fungous Diseases of Plants.

The Department of Plant Pathology desires to aid the farmers of the State through correspondence on plant diseases. Inquiries concerning the identity of diseases and the best method of treatment will be given prompt and careful attention. When writing it is always advisable to send specimens of the diseased plants. The specimens should be wrapped in paper, then packed in a pasteboard box and mailed without delay. Addressed mailing tags will be sent to all who request them for this purpose. We also desire reports upon the prevalence and injury of plant diseases. Reports upon the appearance and extent of epidemics are especially desired.

The Department issues reports of a Plant Disease Survey of Virginia which will be sent free to all who request it, but it is not sent to our regular mailing list. The report is especially valuable for teachers in schools where agricultural subjects are taught.

Address all inquiries to Department of Plant Pathology, Experiment Station, Blacksburg, Va.

AVAILABLE BULLETINS

VIRGINIA AGRICULTURAL EXPERIMENT STATION

Any or all of the following bulletins published by the Station will be sent free to anybody in Virginia who requests them, so long as the supply lasts. If you are interested in farming, have your name placed on our mailing list to receive new bulletins as issued. Bulletins not listed here are now out of print.

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Bulletin 184—Impurities in Grass and Clover Seed Sold in Virginia.
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Circular 3—Dates of Seeding Winter Grains.
Circular 4—Selecting Seed Corn.
Circular 5—Analyses of Sugar Beets in 1908.
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Bulletin 185—The Production of Clean and Sanitary Milk.
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Bulletin 189—Some Diseases of Swine.
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Bulletin 194—Milk Standards.
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FRUITS AND VEGETABLES

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Bulletin 142—The Bitter-rot of Apples.
Bulletin 143—The Composition of Apples.
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Bulletin 147—Bush Fruits.
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Bulletin 191—Cabbage Club-root.
Bulletin 192—Tomato Blight and Rot.
Bulletin 195—Foliage Diseases of the Apple.
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ANNUAL REPORTS

These contain the results of the more technical investigations and are not sent to farmers except on special request. Reports for 1908, 1909 and 1910 now available.

Address correspondence to

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